Floods and Droughts in the Czech Republic - - Analysis of Extreme Discharges in the Upper Svratka-River Catchment

Jiri Sklenar

Masaryk University

Czech Hydrometeorological Institute

INTERNATIONAL TRAINING WORKSHOP ON COMBATING DESERTIFICATION

5-25 September 2010, Gansu, Wuwei, People´s Republic of China

CZECH REPUBLIC

Area :	**78,866 km²**	**Population :**	**10.3 million (2007)**
The lowest point :	**115 m a.s.l.**	**Build-up areas :**	**2%**
The highest poit :	**1,602 m a.s.l.**	**Agricultural land :**	**54%**
Mean temperature :	**7.5 º C**	**Forest land :**	**33%**
Mean precipitation total :	**668 mm**	**Water area :**	**2%**

Borders : Germany, Poland, Austria, Slovakia

Population density : 130 inhabitants / km^2

Capital: Prague (1.2 million inhabitants)

Specific runoff : q=6,1 $l.s^{-1}.km^{-2}$, runoff coefficient : φ=28.8 %

MAIN CATCHMENTS

Labe River Catchment : 63%, Morava River Catchment : 27%, Odra River Catchment : 9% of Czechia´s territory, total length of all watercourses :76,000 km, drainage density : 0.96 km.km^{-2}

MASARYK UNIVERSITY, FACULTY OF SCIENCE

DEPARTMENT OF GEOGRAPHY

- **The city of Brno is the second largest centre of education in the Czech Republic, Masaryk University is the second largest university (about 36,000 students in 2007) : www.muni.cz**
- **Faculty of Science, Department of Geography – My doctoral studies started in 2007 – physical geography**

EDUCATION : http://www.geogr.muni.cz/en/studium/

- **Bachelor study** – geography, cartography, applied geography, teaching geography
- **Master study** – physical geography, regional geography, cartography and geoinformatics, teaching geography
- **Doctoral study** – physical geography, regional

RESEARCH ACTIVITIES

CZECH HYDROMETEOROLOGICAL INSTITUTE (CHMI)

- CHMI BASIC PURPOSE :
  - carry out the function of the Czech Republic´s governmental institution for the fields of hydrology, meteorology, climatology and air quality
  - monitoring, acquisition, processing of hydrometeorological data,   Web site : **www.chmi.cz**
- DIVISION OF HYDROLOGY
  - providing specialist services to state administration
  - serving as centre of the Flood Forecasting Service
  - producing of standard hydrological data
  - providing official discharge measurements in water streams
- FOUNDER : Ministry of the Environment of the Czech Republic

MAIN RIVERS IN THE CZECH REPUBLIC

North Sea Drainage Area

Labe River, Q_a=308 $m^3.s^{-1}$, A=51,394 km^2, l=379 km, q=6 $l.s^{-1}.km^{-2}$

Odra River

Baltic Sea Drainage Area

Black Sea Drainage Area

Vltava River Q_a=149 $m^3.s^{-1}$, A=28,098 km^2, l=440 km

q=5.3 $l.s^{-1}.km^{-2}$

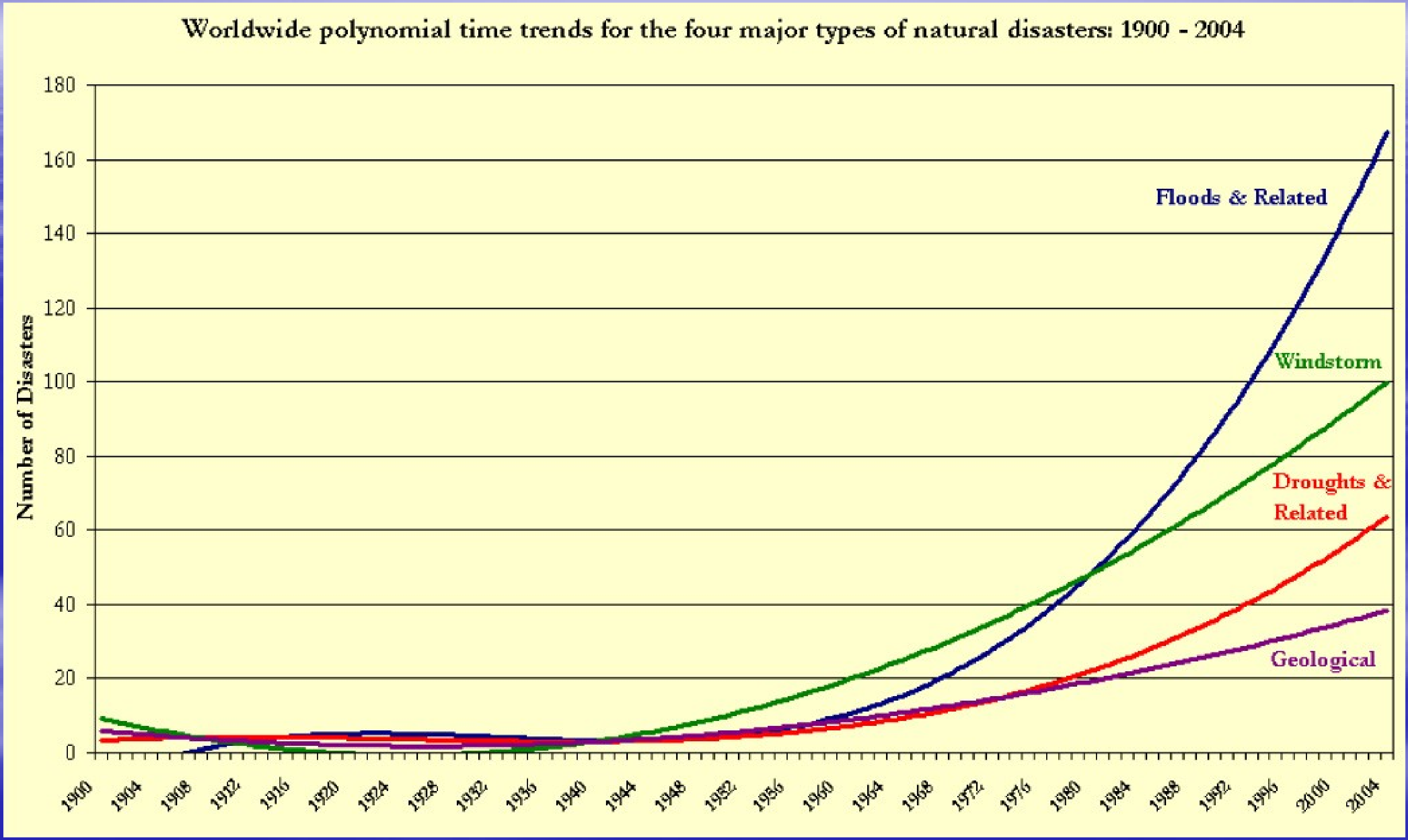
Morava River Q_a=120 $m^3.s^{-1}$, A=23,580 km^2, l=358 km - tributary of Danube River

q=4.5 $l.s^{-1}.km^{-2}$

NATURAL AND HYDROLOGICAL EXTREMES

- Impacts of climate change on water recources and hydrological regime are evident
- The recent period of global warming is characterized by the increased occurrence of natural extremes
- It is also valid for watercourses with the occurrence of hydrological extremes – FLOODS and DROUGHTS
- Problem not only in the Czech Republic and in Europe but all over the world

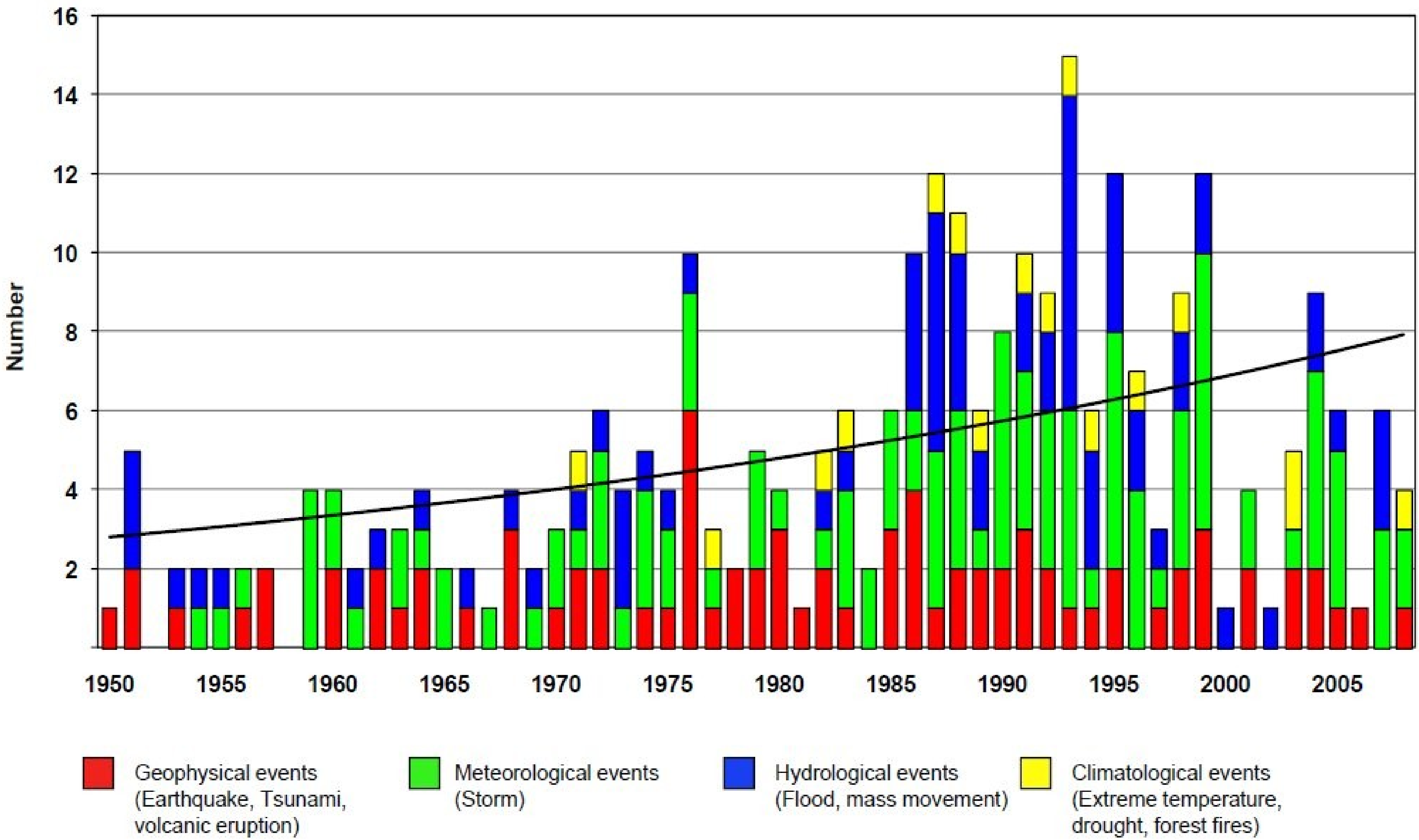
TREND IN DISASTER OCCURENCE 1900-2004



Source: EM-DAT : The OFDA/CRED International Disaster Database.
http://www.em-dat.net, UCL - Brussels, Belgium

Great natural catastrophes 1950 – 2008

Number of events with trend

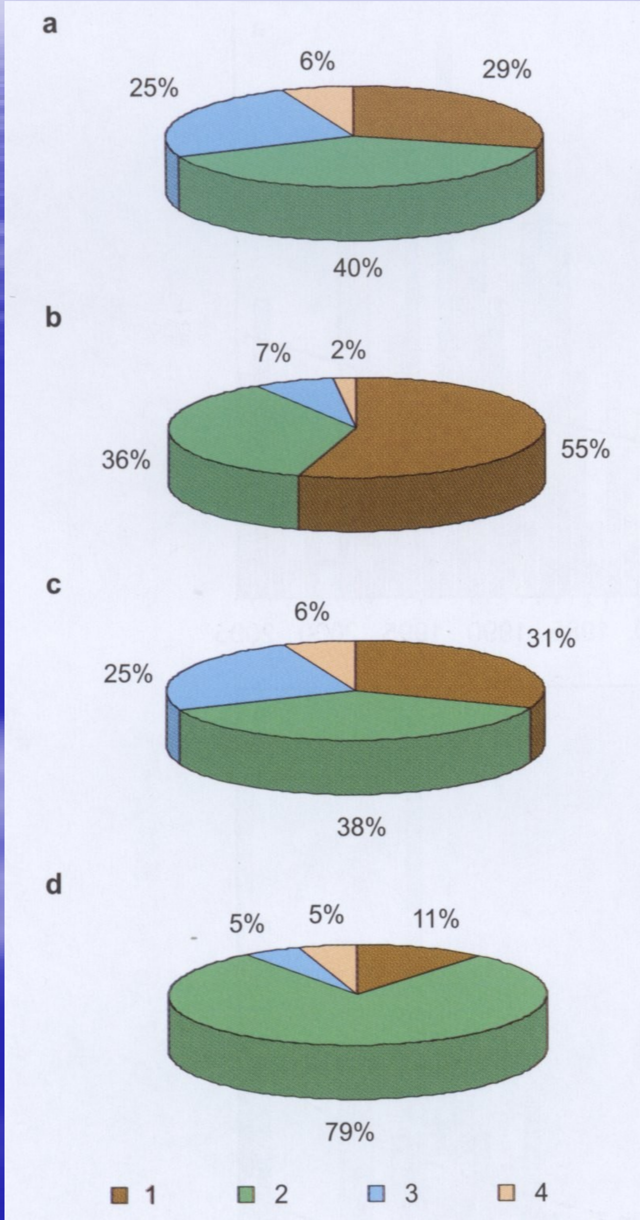


As at January 2009

FLOODS AND NATURAL EXTREMES

- **Definition „Great natural disasters“** (According to the United Nations definition criteria) :
- **The affected region's ability to help itself is distinctly overtaxed,** and interregional or international assistance is necessary (thousands are killed, hundreds of thousands are made homeless).
- Natural extremes increased in frequency over the 20th century from around 10 events per year at the beginning of the century to over 450 events at the end. (E. Bryant, ed., 2005)
- Totally, 2 389 floods occurred during the 20th century. Floods were the second most frequent natural extreme in the world (after tornadoes) with the cost of approximately 207 billion USD. Earthquakes have been the costliest natural extreme (249 billion USD).
- Floods took the first place among natural extremes as for the number of people killed during the 20th century - 6.9 million people died, approx. half from that number died during floods in China in July 1931 (3.7 million people) (E. Bryant, ed., 2005).

Percentage shares of natural extremes in world natural disasters in the period 1960-2005



Source : Munich Re, 2006,
Published by R. Brázdil et al., 2007

a – number of events

b - fatalities

c - overall losses

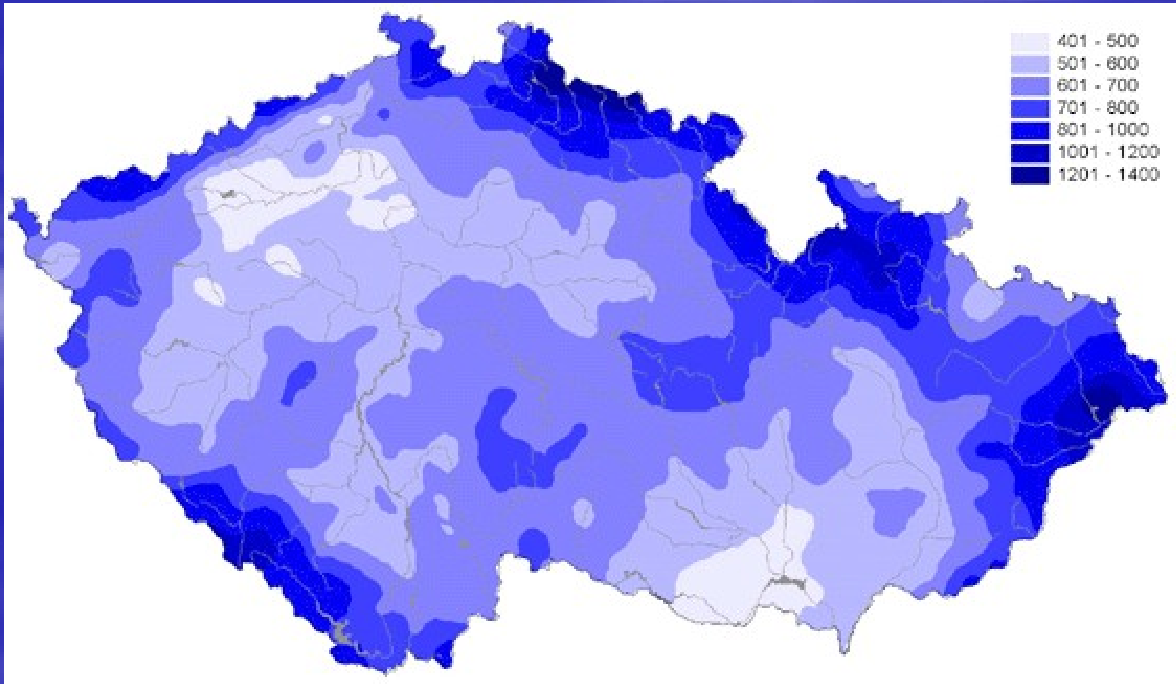
d - insurance losses

1 - earthquake (tsunami,volcanic eruption),
2 - strong wind, 3 - flood, 4 - others

FLOODS – THE CZECH REPUBLIC

- Location of the landlocked country in the temperate climate in central Europe and diverse orography affect to a considerable degree flood regime of the Czech watercourses
- Floods can most often occur during snowmelt on majority of watercourses, usually from December to April, the summer floods can prevail in Odra River basin and on some watercourses originating in mountains, BUT
- Floods can appear several times a year in any season of the year
- The lead-time ranges between few and 36 hours

MEAN ANNUAL PRECIPITATION [mm]



TYPES OF FLOODS – THE CZECH REPUBLIC

With respect to meteorological causes, floods can be devided into :

- RAIN FLOODS, SNOW FLOODS, MIXED FLOODS, ICE FLOODS (Brázdil, R. et al.,2005)

With respect to the combination of causes and seasonal occurence :

- SUMMER TYPE of floods due to
  - Short storm rainfall (flash floods)
  - Regional rainfall – duration up to several days
- WINTER and SPRING TYPE of floods due to
  - Snow melt or combination of snow melt and rainfalls
  - Occurence of mass of ice in the river channel
- FLOOD FROM OTHER SPECIFIC REASONS
  - Blocking of the flow (e.g. by landslide, avalanche)

(Matějíček, J.-Hladný, J., 1999)

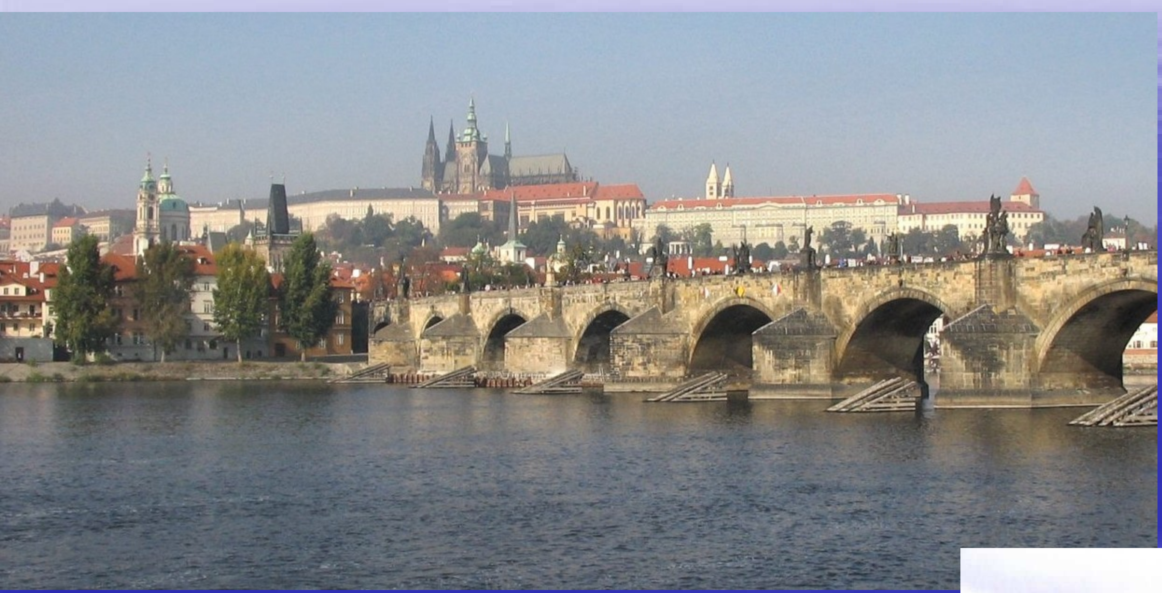
FLOODS – THE CZECH REPUBLIC

- The disastrous floods in the Czech Republic in July 1997 (Moravia, 52 victims, 3.1 billion USD) and in August 2002 (Bohemia, 17 victims, 3.7 billion USD) reached peak discharges with the return period exceeding 100 years and more (also spring 2006)

Prague, Vltava River August 2002, Q_{200}-Q_{500}

Podhradi nad Dyjí, Dyje River, spring 2006 Q_{100}, summer 2006, Q_{200}-Q_{500}

VLTAVA RIVER IN PRAGUE



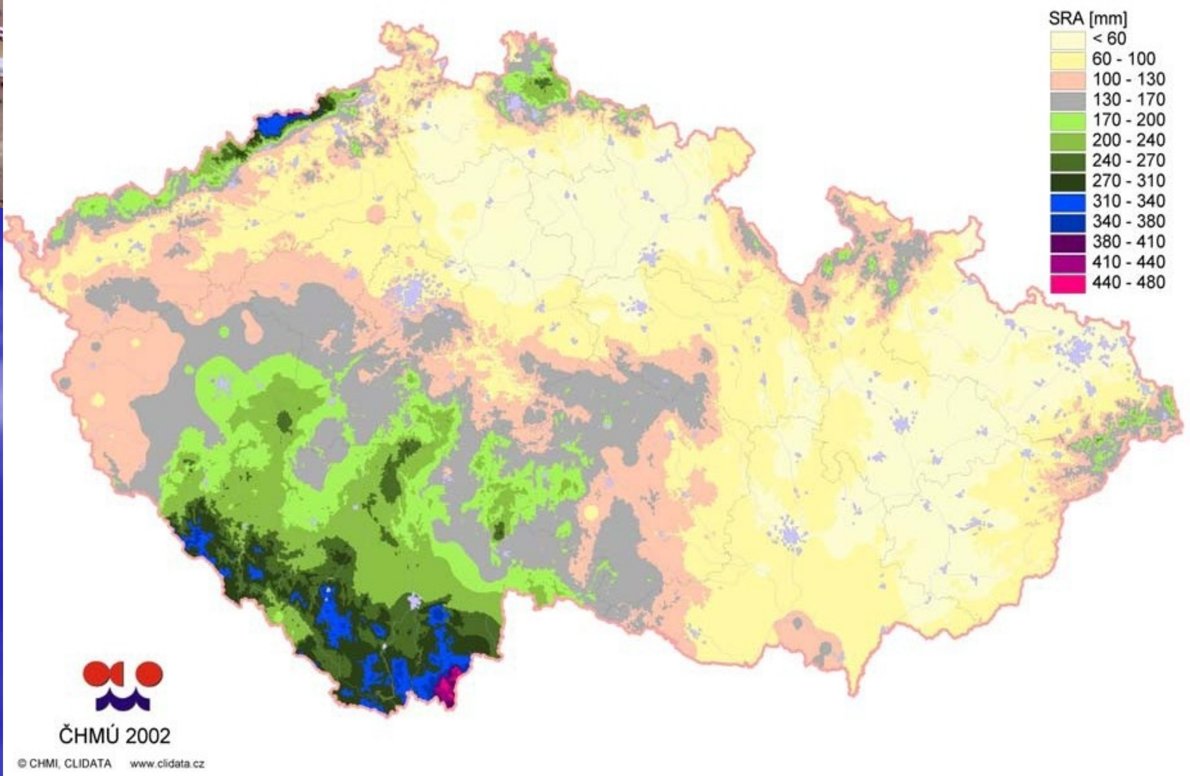
Long-term average :
Water level : H_a=74 cm
Discharge : Q_a=149 $m^3.s^{-1}$

14 August 2002
water level : H=782 cm
peak discharge : 5,160 $m^3.s^{-1}$
(between Q_{200} and Q_{500})

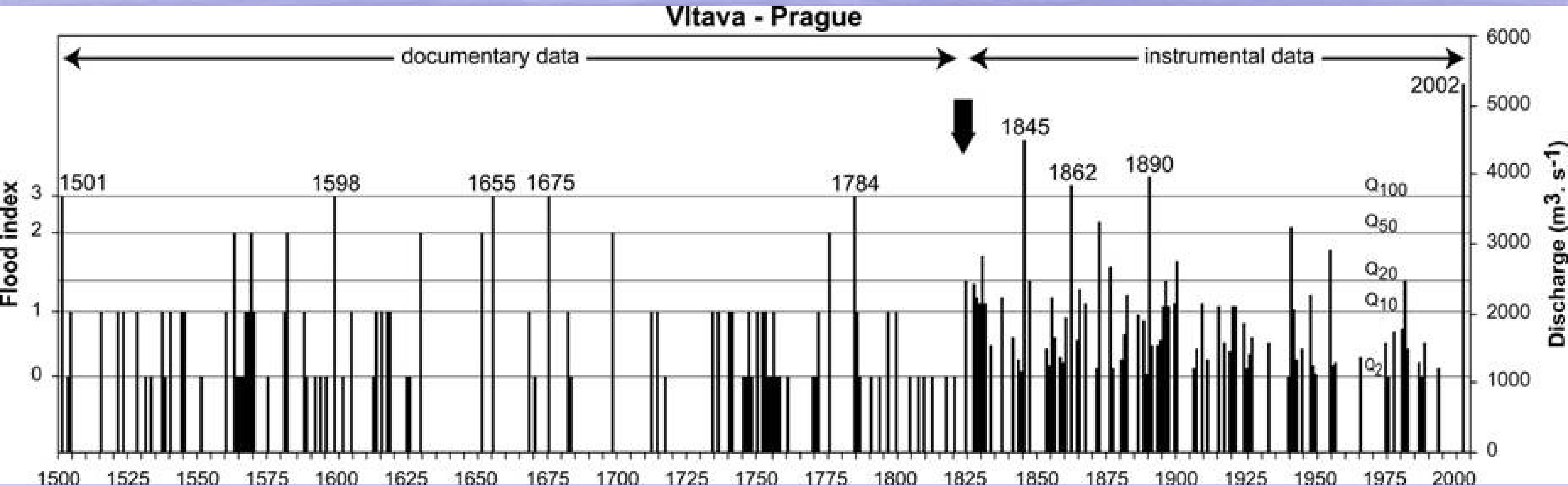
VLTAVA RIVER IN PRAGUE

Long-term average :
H_a=74 cm, Q_a=149 $m^3.s^{-1}$
14 August 2002 - water level :
H=782 cm, peak discharge :
5,160 $m^3.s^{-1}$
(between Q_{200} and Q_{500})

Precipitation totals
for the period
6-15 August 2002



VLTAVA RIVER IN PRAGUE

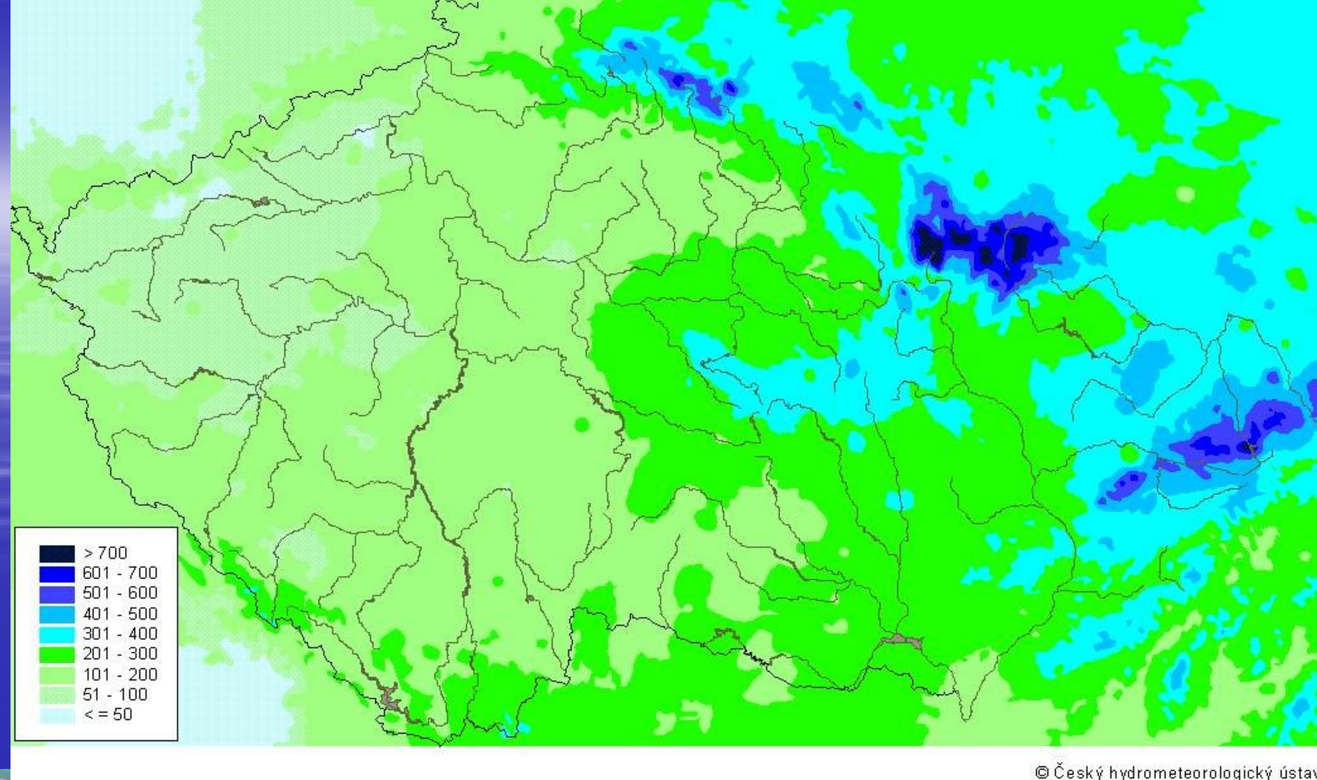


The synthesis series of flooding derived from documentary evidence and water-gauge measurements - the Vltava River in Prague during 1500-2002 (R. Brázdil, Masaryk University, Brno)

H_a=74 cm, Q_a=149 $m^3.s^{-1}$, 14 August 2002 - water level H=782 cm, peak discharge $Q_{200\text{-}500}$=5,160 $m^3.s^{-1}$

FLOODS

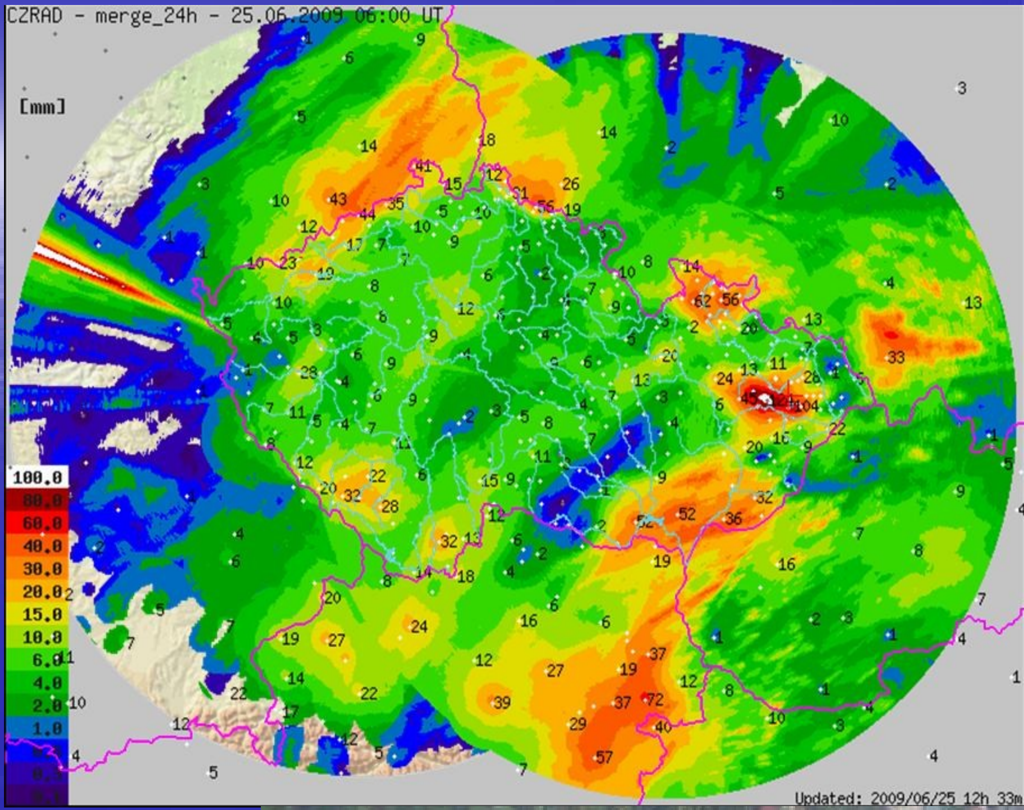
Monthly precipitation totals - July 1997 [mm]



Flooded Troubky village, July 1997
River Bečva took 9 human lives

Morava River, Olomouc
11 July 1997

Flash floods in June and July 2009



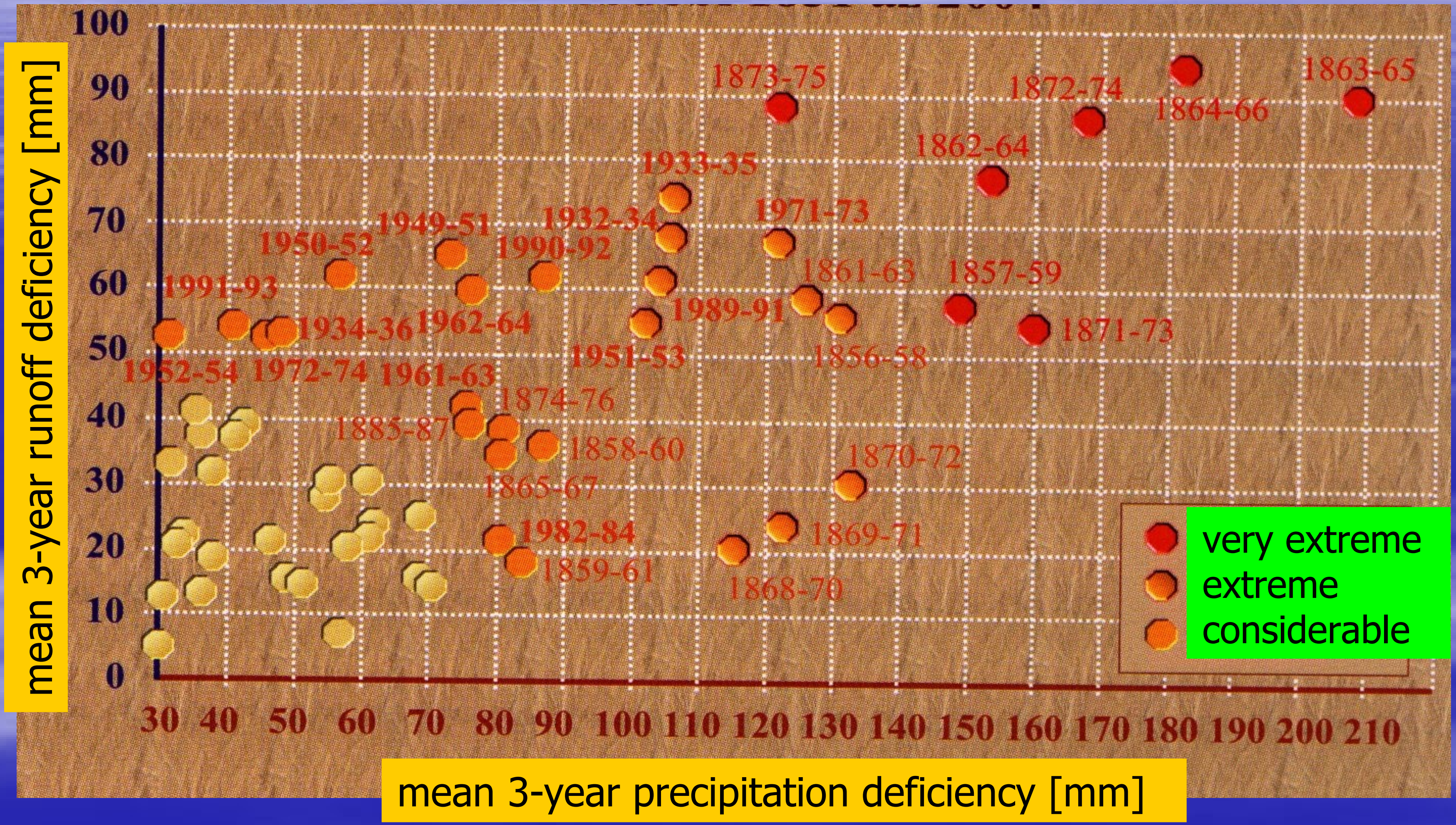
- Extreme hydrological phenomena in summer 2009
- Humid warm air moved to the Czech Republic from the east
- Local but very intensive flash floods were caused by torrential precipitations
- Occurrence during almost 2 weeks at the turn of June and July 2009 in the evenings and during nights in the middle and north parts of Moravia, in the south and north parts of Bohemia
- 15 victims, damage approx. 425 million USD
- the third most disastrous floods since 1993
- Novy Jicin area hit (Odra River Catchment) - 24 June 2009 - Bělotín station - up to 124 mm
- small watercourses affected - rivers Jičínka and Luha - water level increased up to 5 m – estimation Q_{100}-Q_{500}
- Jičínka - Nový Jičín - during 3 hours – water level increased from 123 cm to 609 cm

Jeseník nad Odrou – Luha River

DROUGHTS – THE CZECH REPUBLIC

- On the other hand, dry periods occurred in the Czech Republic, for example, at the beginning of the 1990s
- Drought - Lack of water
  - consequences can persist even after the end of dry periods
  - great areas can be affected
  - serious impacts
- Meteorological, agricultural, hydrological drought
- Meteorological drought – primary cause (precipitation) – may be reflected in drying and cracking of the soil
- Hydrological drought – a delayed occurrence after meteorological drought
- The largest meteorological and hydrological droughts in the 20th century (coinciding) : 1932-1935, 1949-1953, 1971-1974, 1989-1992
- The areas with the annual precipitation total less than 500 mm can be considered drought zones in the Czech Republic
  - These areas are located mainly in the southeast part of the country. Mean annual air temperature exceed 9°C in these areas.

DROUGHTS – THE CZECH REPUBLIC
(meteorological and hydrological droughts)
1851-2004

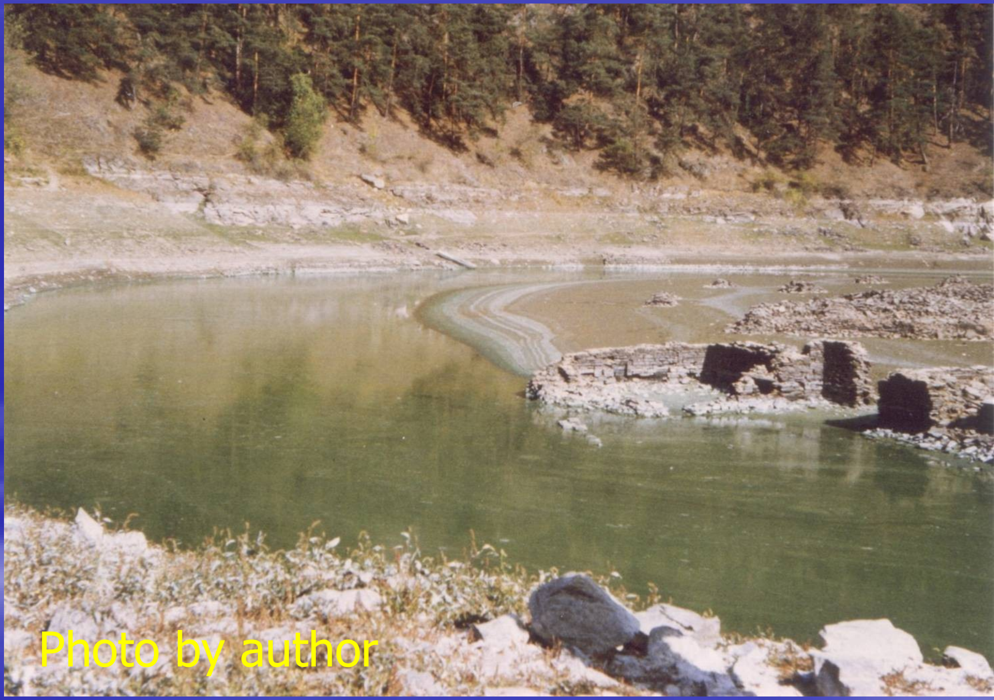


Source: Nemec, J. – Hladny, J., eds. (2006)

DROUGHTS - THE CZECH REPUBLIC -
- impact on watercourses

- Dry periods occurred in the Czech Republic, for example, 1983, at the beginning of the 1990s (1989 - -1992), 1994, 2000, 2003 - Morava River Catchment

Lanžhot, Morava River
August 2003



Vranov Water Reservoir, Želetavka River inflow into Dyje River, 27 September 1992 (5-6% of Q_a)

HYDROLOGICAL DROUGHTS – THE CZECH REPUBLIC

- Hydrological drought is reflected in a noticeable drop of discharges, or even by water streams drying up

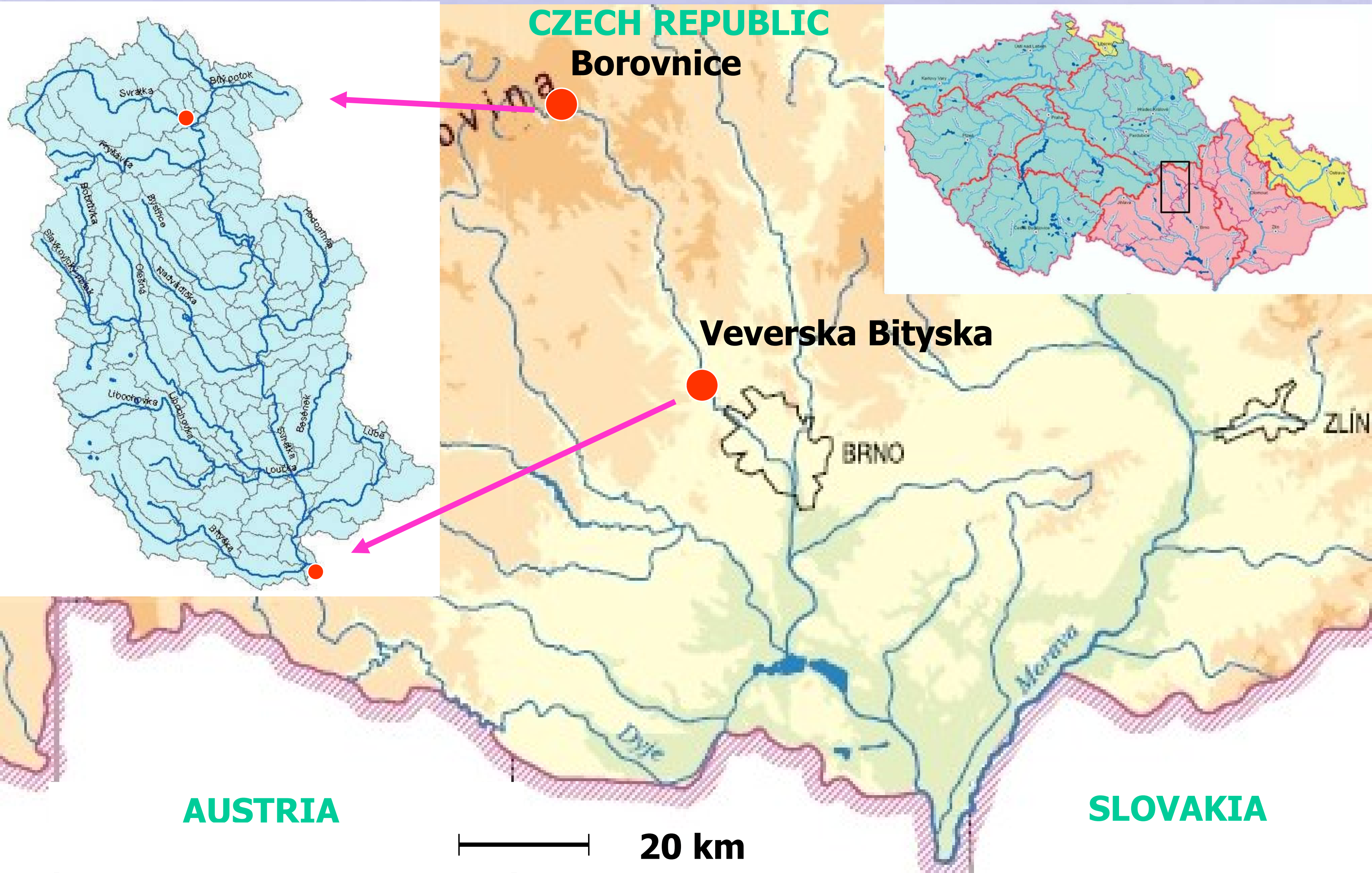
The dried up bed of the Kladenka (Olsava River Catchment, tributary of the Morava River), 23 Sept. 2003, Q_a=0.2 $m^3.s^{-1}$, photo : L. Budik

Vranov Water Reservoir, Želetavka River inflow into Dyje River, 27 Sept. 1992, former Bítov village flooded by construction of the reservoir (in 1930-34)

DATA AND SELECTION OF THE TERRITORY STUDIED (PhD thesis)

- 11 hydrological stations
- Series of the mean annual and monthly discharges
- Series of the annual peak discharges
- Selected period of assessment :
  - Svratka River, Station Borovnice : 1925-2007
- Territory of interest : upper part of the Svratka River Catchment, catchment area A = 1480.55 km^2
- Located in the middle part of Moravia (Czech Republic)

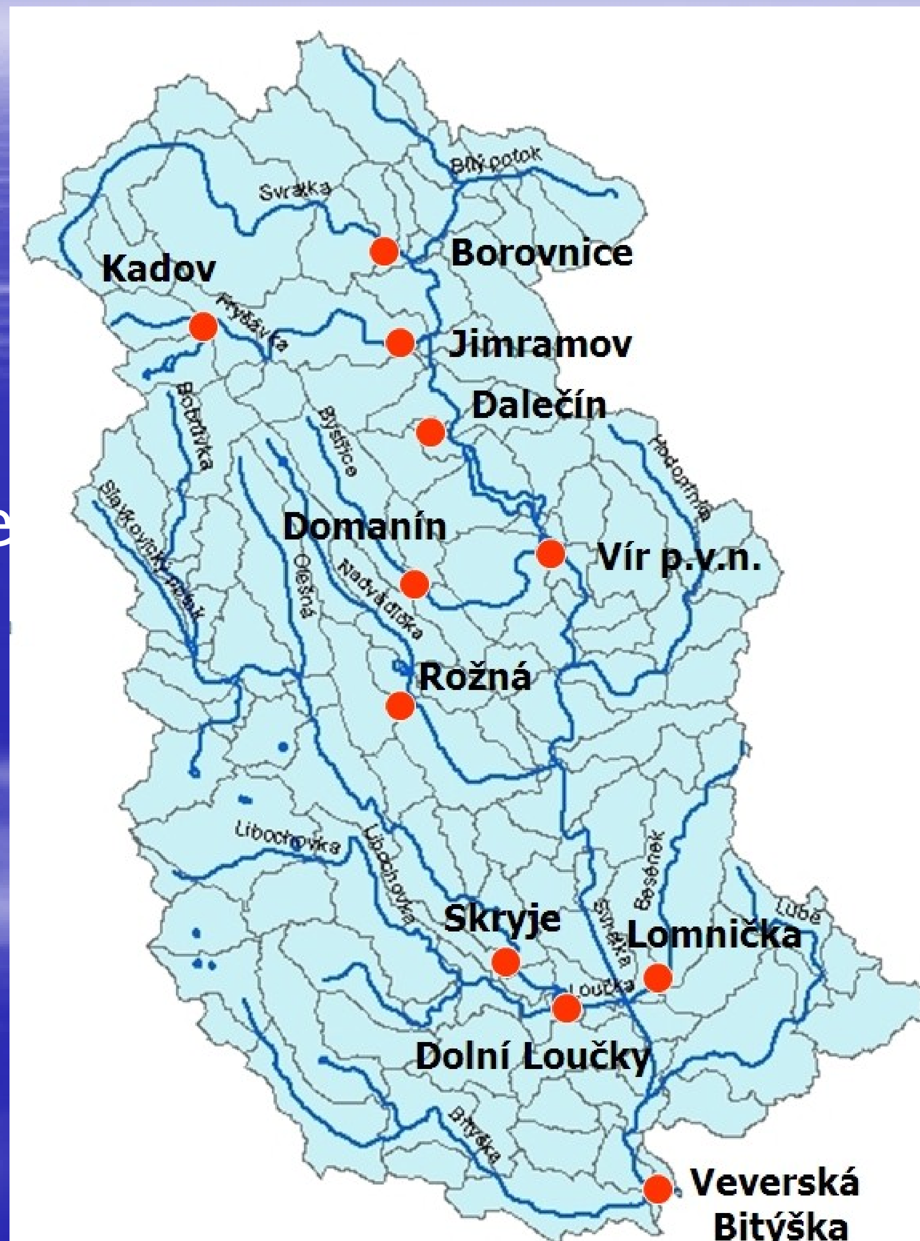
Selection of the territory studied



Selected area - hydrological stations

Catchment area
$A=1480.55\ km^2$
(20.8 % of the total area of the Svratka Catchment)

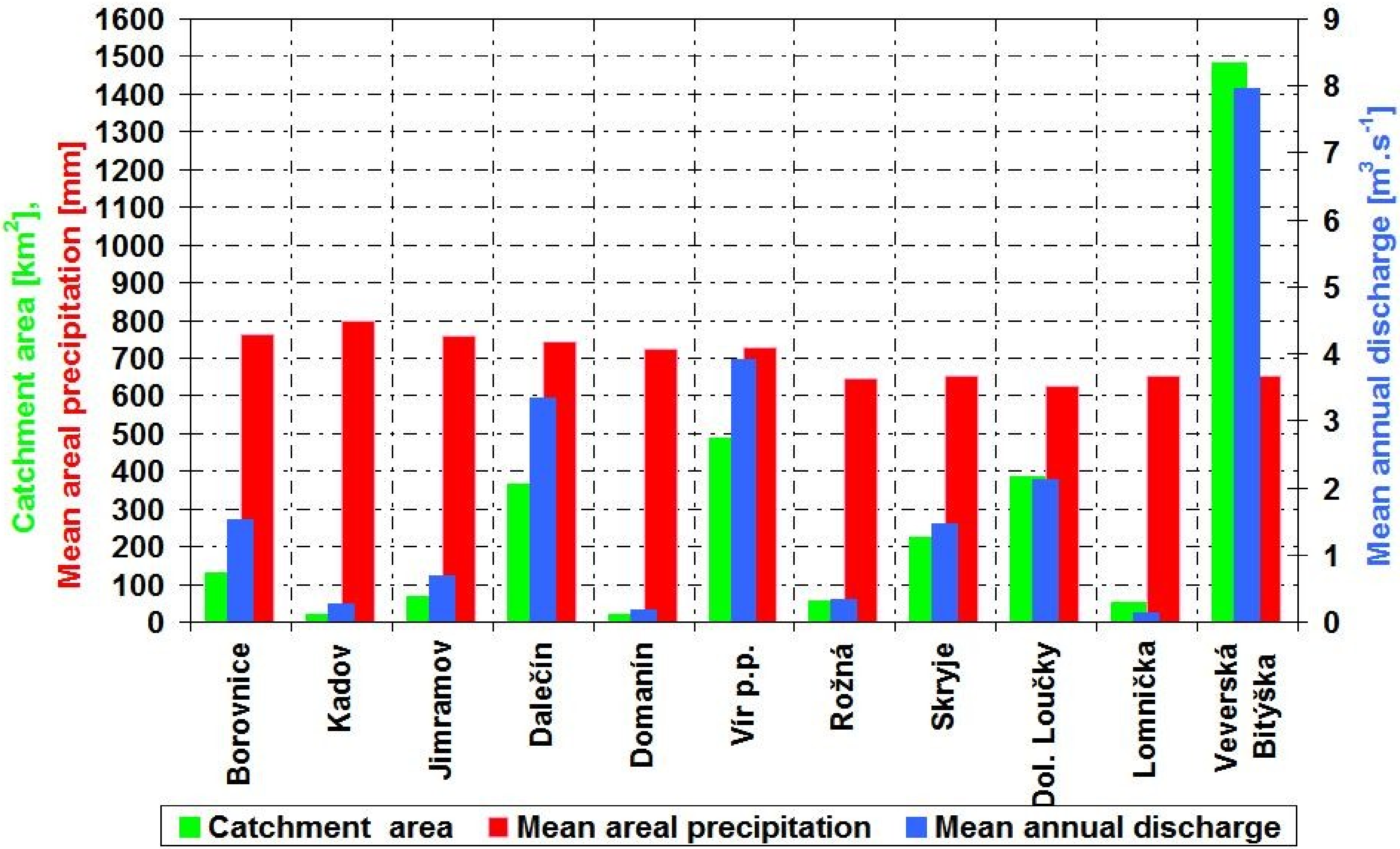
Mean areal precipitation
$P_a=653\ mm$



Long-term mean annual discharge
$Q_a=7.96\ m^3.s^{-1}$

Peak discharge with the return period of 100 years
$Q_{100}=280\ m^3.s^{-1}$

Hydrological stations

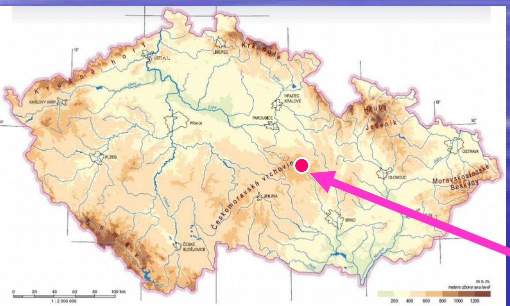


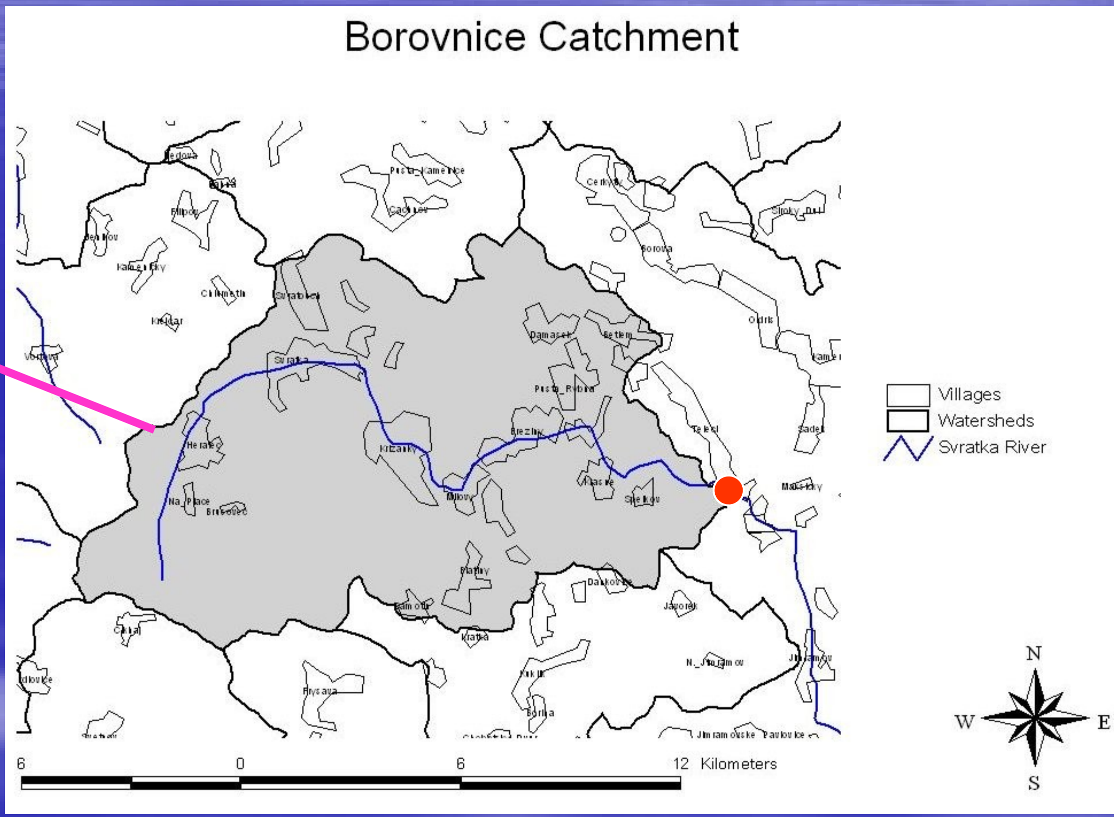
METHODOLOGY

- In the period of systematic hydrological observations, floods which exceeded the value Q_2 (peak discharge with the return period of 2 years) were chosen from the CHMI database
- N-year discharges were applied (for N=2, 5, 10, 20, 50, 100) – derived in accordance with the methodology used in CHMI, calculated from the values of maximum peak discharges from all of hydrological years)
  - data series are sufficiently long
  - discharges are mostly not affected by water reservoirs (geografical location - catchments are located in upper parts of selected rivers)

River Svratka, Station Borovnice, Period 1925-2007

Basic hydrological characteristics



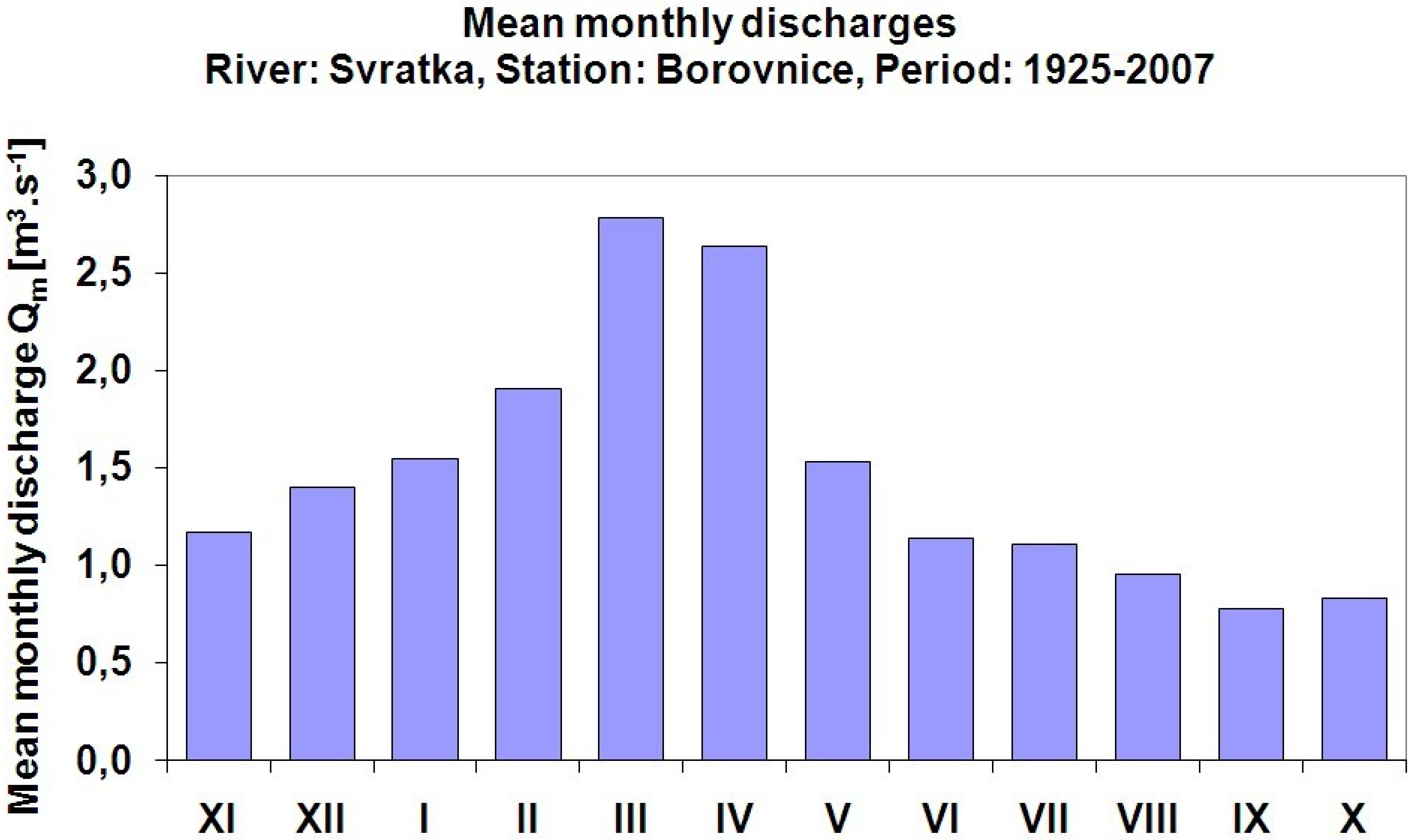


- Catchment area
  $A=127.95\ km^2$ (i.e. 1.8% of the total area of the Svratka catchment)
- Long-term mean annual discharge $Q_a=1.52\ m^3.s^{-1}$
- Mean areal precipitation
  $P_a=764$ mm
- Absolute maximum of 60 $m^3.s^{-1}$ occurred in July 1965

Peak discharges analysis - example - hydrological station Borovnice - Svratka River

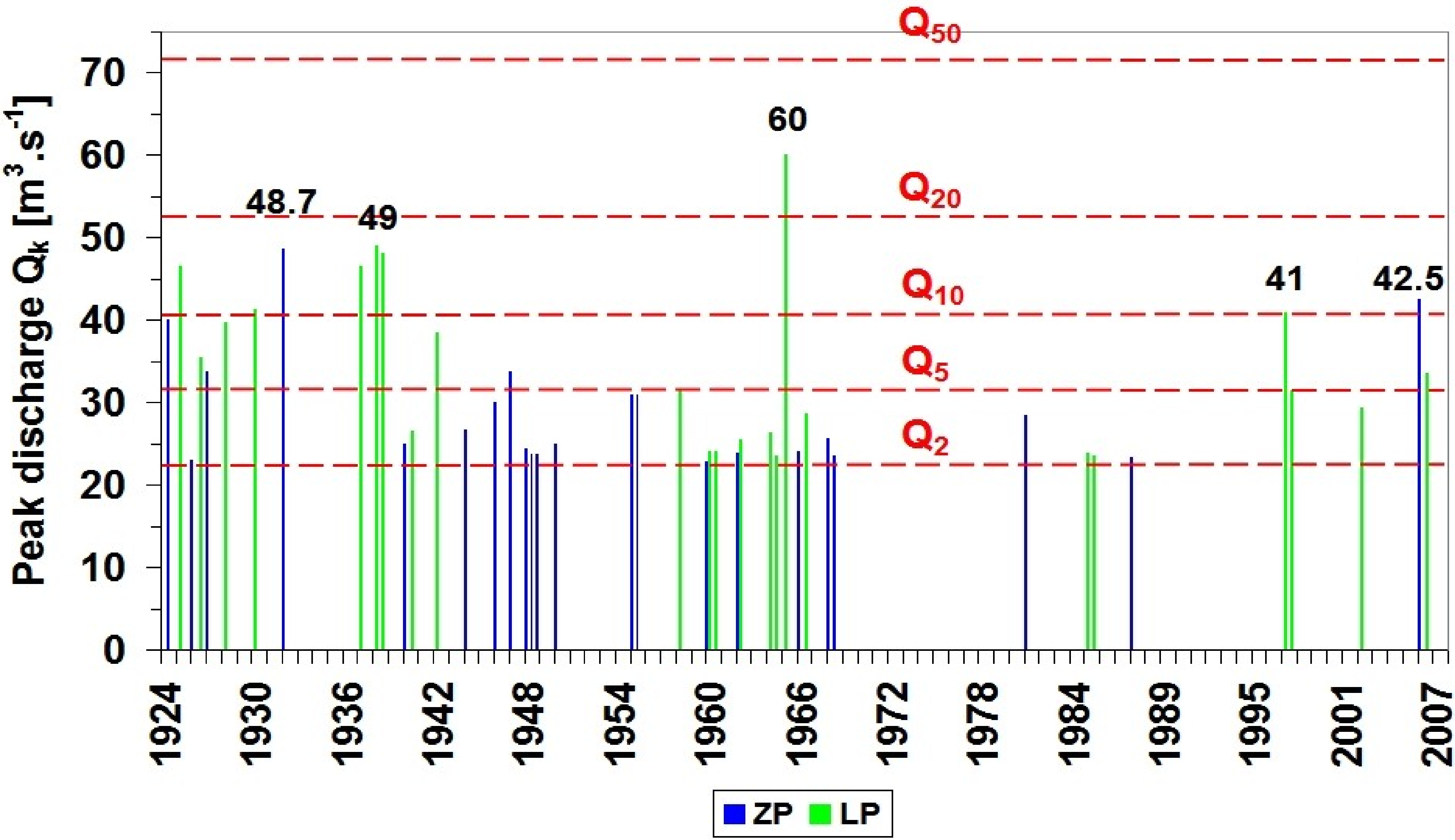
Flood situation – approx. Q_5, village Borovnice, July 1997, photo : I. Dostál

Hydrological station Veverska Bityska, Svratka River, 11 October 2007, photo by author



the heighest monthly discharges - March (15.7% of R_a) and April (14.8%), the lowest monthly discharges in Semptember (4.4%) and October (4.7%)

Chronology of floods exceeding the two-year maximum peak discharge $Q_2 = 22.3\ m^3.s^{-1}$ in the period 1924-2007, taking into consideration their N-year return period and occurence during the winter (ZP : from November to April) and summer (LP : from May to October) hydrological half-years River : Svratka, Station : Borovnice



Frequencies of floods according to the N-year return period of their maximum peak discharge Q_k on the Svratka River at Borovnice Station in the period 1925-2007

Period/Q_k	$Q_2<Q_k<Q_5$	$Q_5<Q_k<Q_{10}$	$Q_{10}<Q_k<Q_{20}$	$Q_{20}<Q_k<Q_{50}$	$Q_{50}<Q_k<Q_{100}$	$Q_k>Q_{100}$	Total
ZP	17	3	2	0	0	0	22
LP	10	6	6	1	0	0	23
Total	27	9	8	1	0	0	45

- The floods with exceeded Q_2 but without reaching Q_5 (60 % - 27 cases)
  were the most frequent.
- The floods exceeding the maximum peak discharge Q_{50} were recorded not at all (the highest return period is 20 < N < 50 – July 1965).
- Floods taking place during winter hydrological half-years : 22 events
- Floods occurring during summer hydrological half-years : 23 events

Svratka River at Borovnice Station

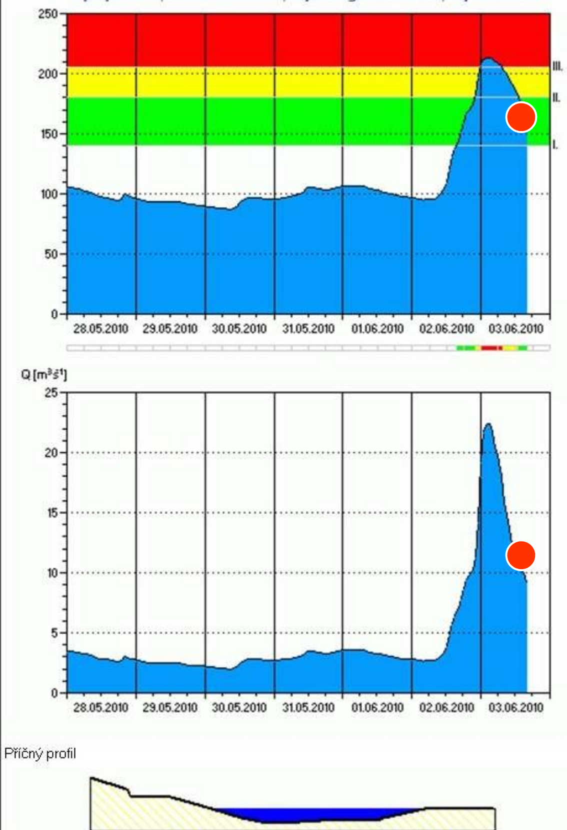
Svratka – Borovnice hydrological station,
9 September 2009, photo by author

Stavy a průtoky na vodních tocích

POVODÍ MORAVY

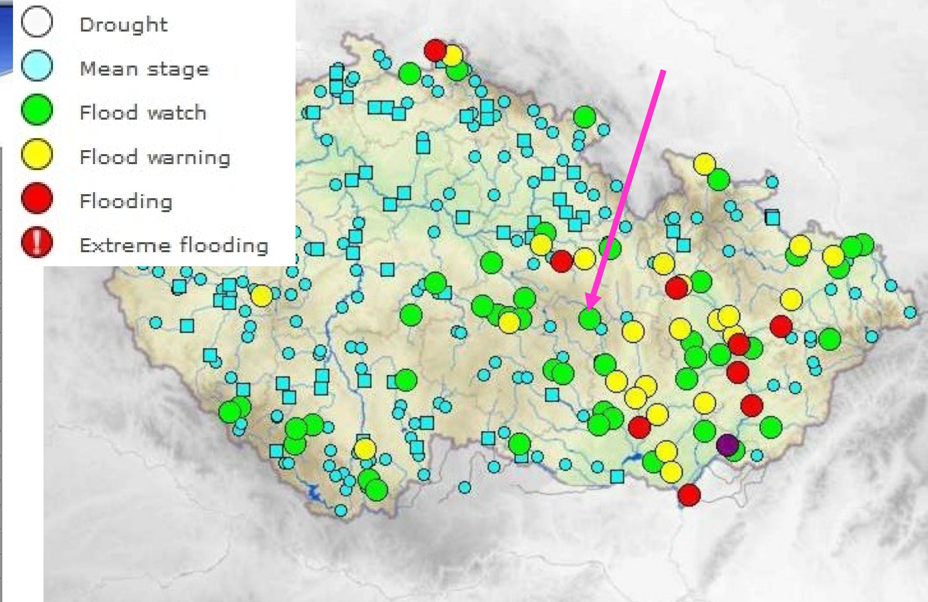
--- Monitorovací stanice (tok - stanice) ---

Celková mapa povodí | Přehled měření | Hydrologická situace | Výstraha



Vodní stav H [cm]:	
03.06.10 16:37	165
03.06.10 16:00	168
03.06.10 15:00	172
03.06.10 14:00	176
03.06.10 13:00	180
03.06.10 12:00	186
03.06.10 11:00	191
03.06.10 10:00	196
03.06.10 09:00	200
03.06.10 08:00	202
03.06.10 07:00	206
03.06.10 06:00	209
03.06.10 05:00	210
03.06.10 04:00	212
03.06.10 03:00	213
03.06.10 02:00	213
03.06.10 01:00	212
03.06.10 00:00	208
02.06.10 23:00	198
02.06.10 22:00	183
02.06.10 21:00	174
02.06.10 20:00	170
02.06.10 19:00	167
02.06.10 18:00	160
02.06.10 17:00	152
02.06.10 05:00	96
01.06.10 05:00	107
31.05.10 05:00	98
30.05.10 05:00	88
29.05.10 05:00	94
28.05.10 05:00	103

Průtok Q [$m^3.s^{-1}$]:	
03.06.10 16:37	9,24
03.06.10 16:00	9,57
03.06.10 15:00	10,01
03.06.10 14:00	10,46
03.06.10 13:00	10,9
03.06.10 12:00	11,62
03.06.10 11:00	12,37
03.06.10 10:00	13,72
03.06.10 09:00	14,8
03.06.10 08:00	15,88
03.06.10 07:00	18,08
03.06.10 06:00	19,82
03.06.10 05:00	20,4
03.06.10 04:00	21,7
03.06.10 03:00	22,35
03.06.10 02:00	22,35
03.06.10 01:00	21,7
03.06.10 00:00	19,24
02.06.10 23:00	14,26
02.06.10 22:00	11,26
02.06.10 21:00	10,23
02.06.10 20:00	9,79
02.06.10 19:00	9,46
02.06.10 18:00	8,7
02.06.10 17:00	7,86
02.06.10 05:00	2,71
01.06.10 05:00	3,63
31.05.10 05:00	2,88
30.05.10 05:00	2,09
29.05.10 05:00	2,55
28.05.10 05:00	3,29



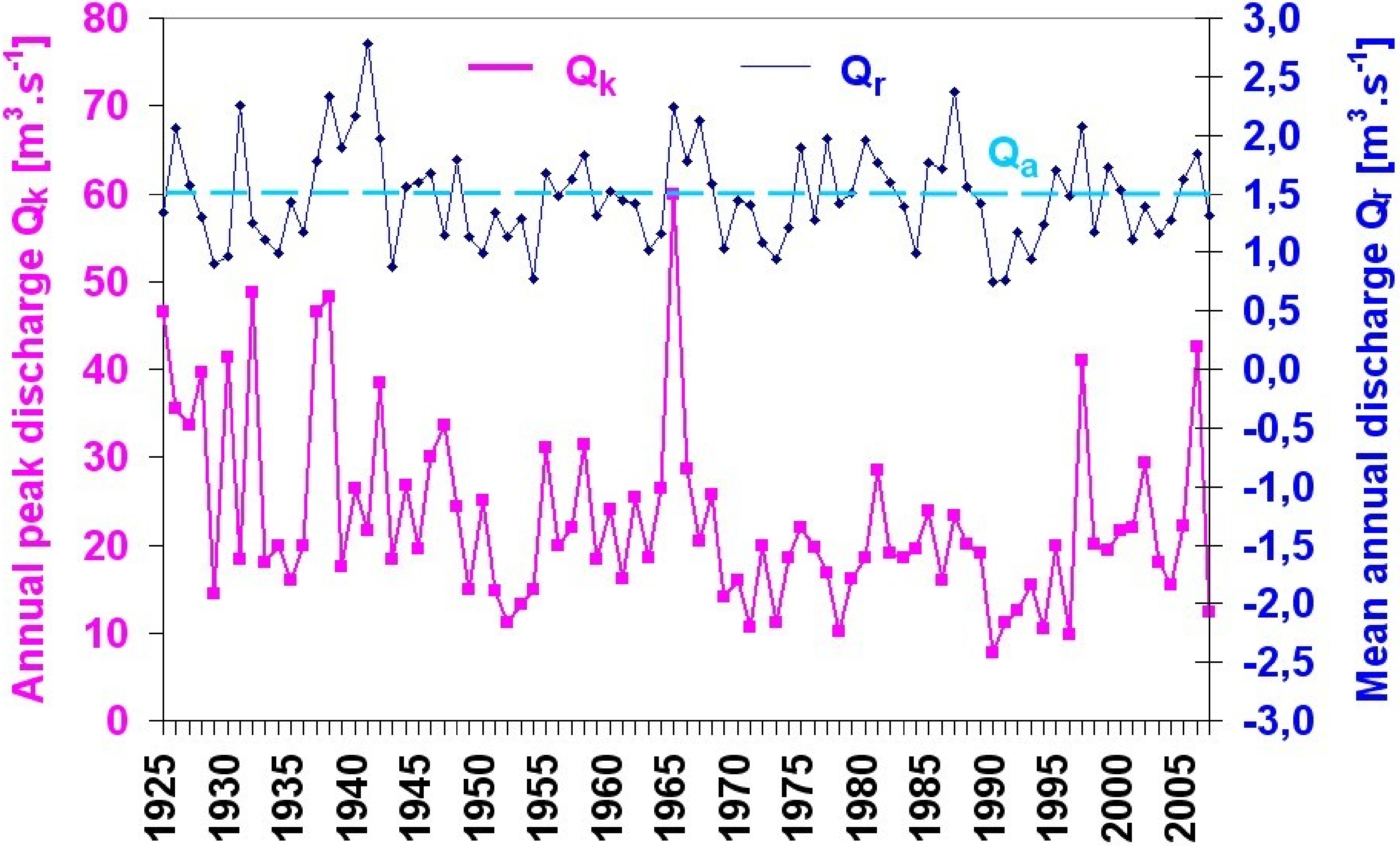
Hydrogram - Borovnice

Increased water level (approx. Q_1-Q_2) on the Svratka River at Borovnice on 3 June 2010 at 1:30 p.m. (13:30 local summer time), photo by author

Monthly frequencies of floods (exceeding the two-year maximum discharge $Q_2 = 22.3\ m^3.s^{-1}$) according to the N-year return period of their maximum peak discharge Q_k during the winter (ZP - November-April) and summer (LP - May-October) hydrological half-years

Month/Q_k	$Q_2<Q_k<Q_5$	$Q_5<Q_k<Q_{10}$	$Q_{10}<Q_k<Q_{20}$	$Q_{20}<Q_k<Q_{50}$	$Q_{50}<Q_k<Q_{100}$	$Q_k>Q_{100}$	Monthly frequency	Frequency ZP/LP	Total frequency
XI	1	0	0	0	0	0	1	22	45
XII	5	0	0	0	0	0	5		
I	3	1	1	0	0	0	5		
II	4	0	0	0	0	0	4		
III	3	2	1	0	0	0	6		
IV	1	0	0	0	0	0	1		
V	3	2	0	0	0	0	5	23	
VI	2	1	0	0	0	0	3		
VII	0	2	2	1	0	0	5		
VIII	4	1	3	0	0	0	8		
IX	0	0	0	0	0	0	0		
X	1	0	1	0	0	0	2		

Mean annual discharges Q_r and annual peak discharges Q_k on the Svratka River at Borovnice station in the period 1925-2007



Rate of runoff during hydrological years including maximum annual peak discharge Q_k, mean annual discharge Q_r and N-year return period of the maximum annual peak discharge Q_k, Station : Borovnice

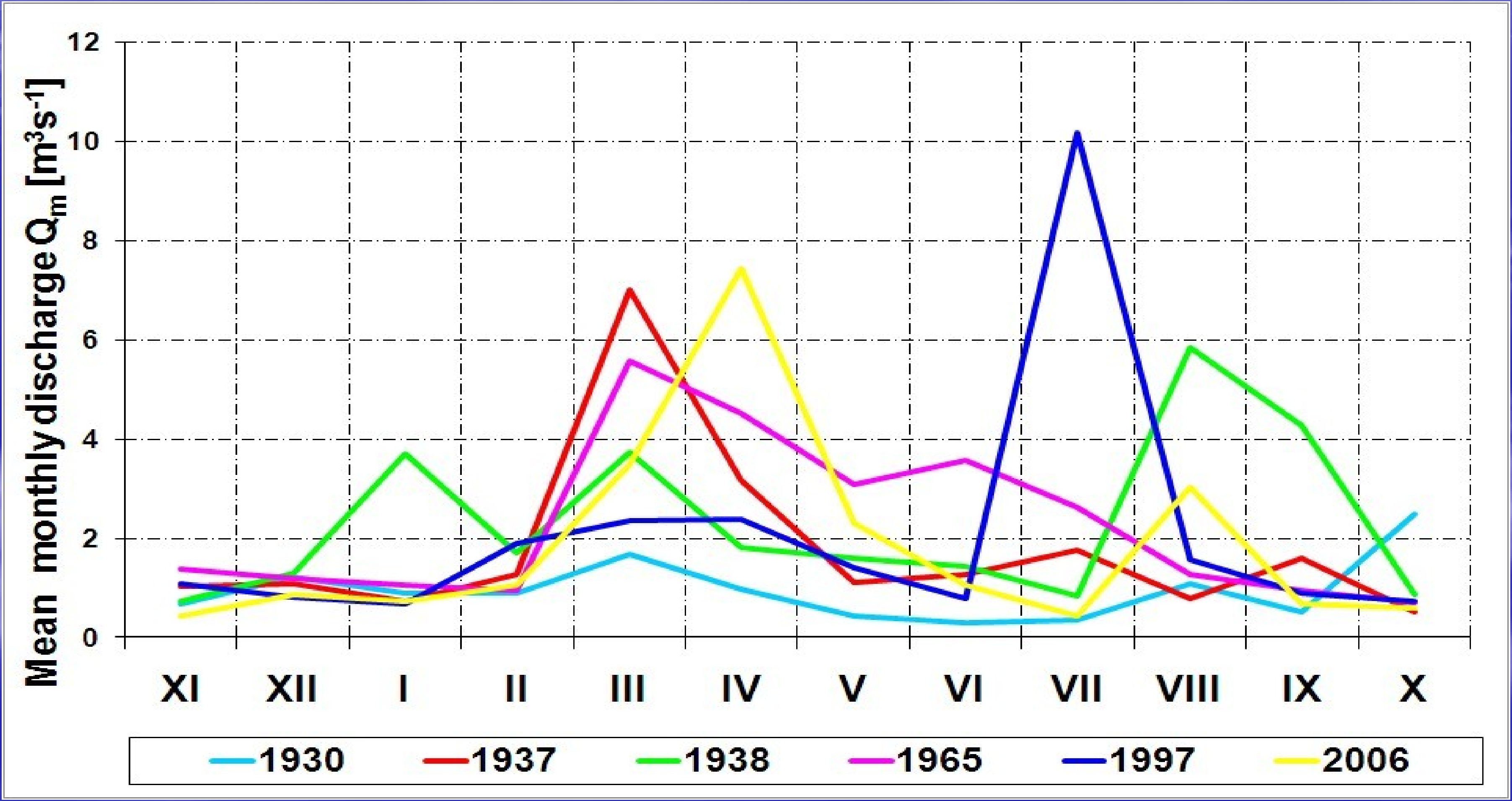
Nr.	Hydrological year (HR)	Mean annual discharge Q_r [$m^3.s^{-1}$]	Exceedance probability p [%]	Maximum annual peak discharge Q_k [$m^3.s^{-1}$]	Rate of runoff during hydrological year	Return period N	Number of floods during hydrological year
1	1941	2.775	0.84	22.0	extremely wet	>1	1
2	1987	2.372	2.04	23.3	extremely wet	>2	1
3	1938	2.327	3.24	49.0	extremely wet	>10	2
4	1931	2.259	4.44	18.3	extremely wet	>1	1
5	1965	2.243	5.64	60.0	extremely wet	>20	1
6	1940	2.166	6.83	26.5	extremely wet	>2	2
7	1967	2.120	8.03	20.5	extremely wet	>1	1
8	1997	2.075	9.23	41.0	extremely wet	>10	2

Table of floods exceeding the ten-year maximum peak discharge $Q_{10} = 40.7\ m^3.s^{-1}$ Station : Borovnice

Nr.	Maximum annual peak discharge $Q_k\ [m^3.s^{-1}]$	Hydrological year	Month	Number of floods during hydrological year	Return period N	Rate of runoff during hydrological year
1	60.0	1965	VII	1	> 20	extremely wet
2	49.0	1938	IX	2	> 10	extremely wet
3	48.7	1932	I	1	> 10	drought
4	46.6	1925	VIII	1	> 10	mean
5	46.6	1937	VII	1	> 10	wet
6	42.5	2006	III	2	> 10	wet
7	41.3	1930	X	1	> 10	extremely drought
8	41.0	1997	VII	2	> 10	extremely wet

Mean monthly discharges Q_m in selected hydrological years with floods exceeding the ten-year maximum peak discharge $Q_{10} = 40.7\ m^3.s^{-1}$

Station : Borovnice



Determination of extremely wet, wet, extremely dry and dry hydrological years

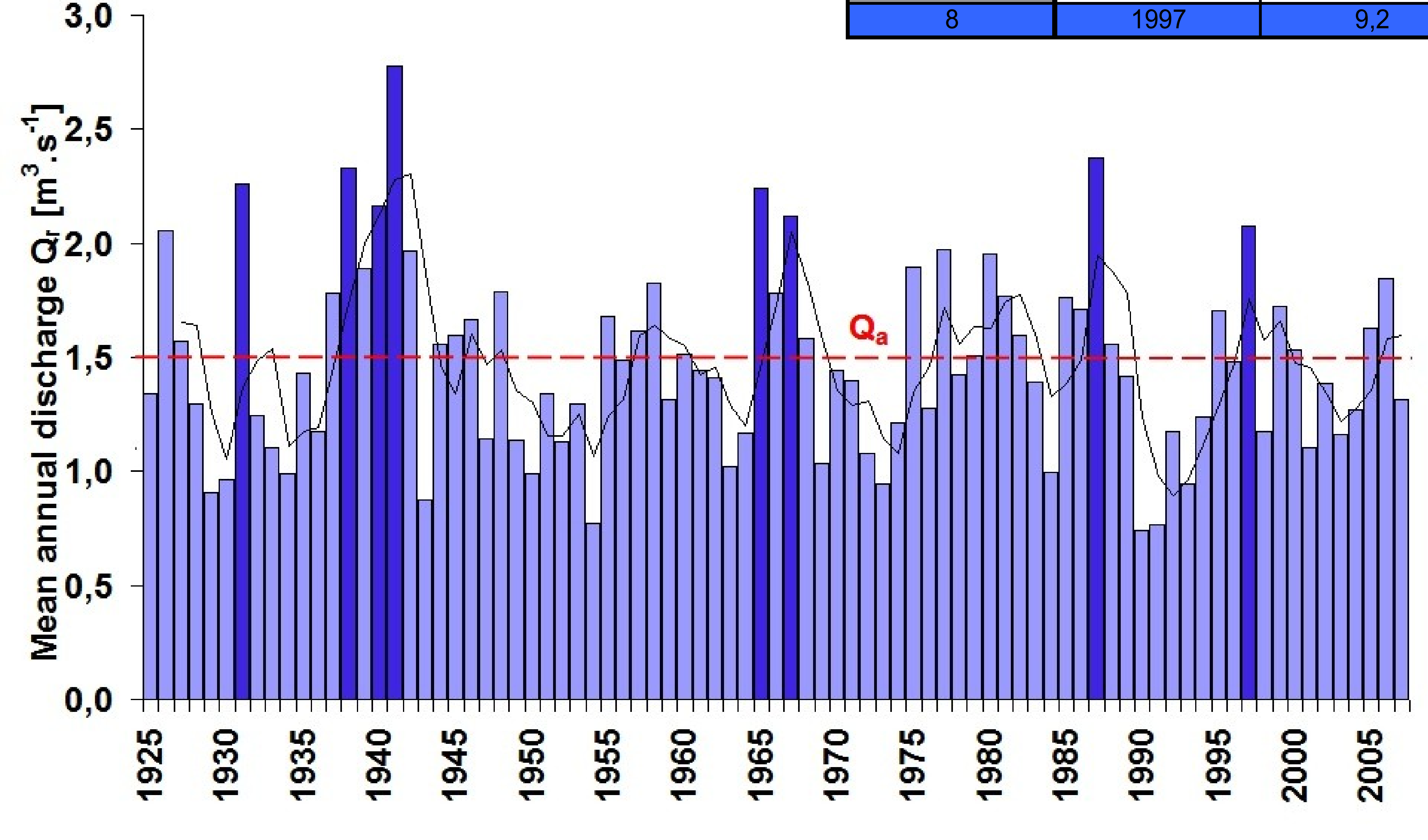
- Calculation the values of exceedance probability according to Cegodajev formula (Netopil, R., 1984) :
- $p[\%]= (m-0.3)/(n+0.4)*100$
  - m – ordinal number of element in file sequenced in descending order
  - n – number of file elements

- Determination of extremely wet, wet, extremely dry and dry years by rate of runoff during hydrological years using the calculated values p :

  - 0 % < p <= 10 % - extremely wet hydrological year
  - 10 % < p <= 40 % - wet hydrological year
  - 40 % < p <= 60 % - average hydrological year
  - 60 % < p <= 90 % - dry hydrological year
  - 90 % < p <=100 % - extremely dry hydrological year

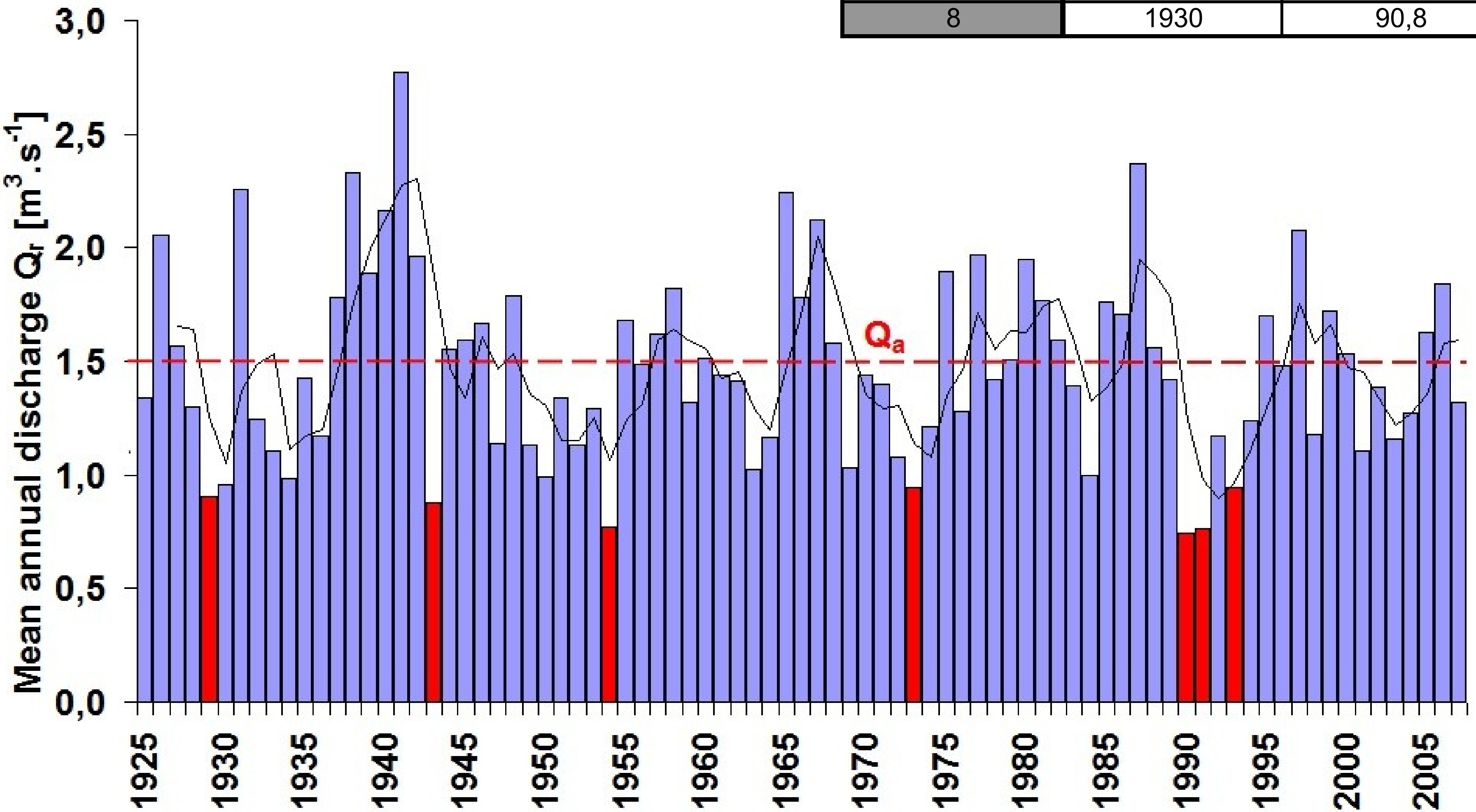
Determination of extremely wet hydrological years by annual rate of runoff - Borovnice

Ordinal number	Hydrological year	Exceedance probability p [%]
1	1941	0,8
2	1987	2,0
3	1938	3,2
4	1931	4,4
5	1965	5,6
6	1940	6,8
7	1967	8,0
8	1997	9,2



Determination of extremely dry hydrological years by annual rate of runoff - Borovnice

Ordinal number	Hydrological year	Exceedance probability p [%]
1	1990	99,2
2	1991	98,0
3	1954	96,8
4	1943	95,6
5	1929	94,4
6	1993	93,2
7	1973	92,0
8	1930	90,8



CONCLUSION

- Floods are natural extremes which are affected by climate change as well as droughts. The impacts of these extremes can be disastrous.
- Despite their negative human impacts, floods and droughts should be considered as natural phenomena and a part of water cycle in the nature.
- Flood and drought protection measures and systems are necessary but the absolute protection is not possible. It is only possible to reduce the harmful impacts of floods and droughts.
- Therefore, the research, monitoring and assessment of floods and droughts remain and will remain an up-to-date topic.

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THANK YOU FOR YOUR ATTENTION

Jiri Sklenar

Masaryk University, Faculty of Science,
Department of Geography (supporting institution)

Office :
Czech Hydrometeorological Institute Prague
Division of Hydrology
Czech Republic